Industrial Decarbonization: Trends, Roadmaps and Actions

Edward G. Rightor, Ph.D.
ACEEE

Louisiana: Industrial Decarbonization Special Session

October 8, 2021

Key Topics

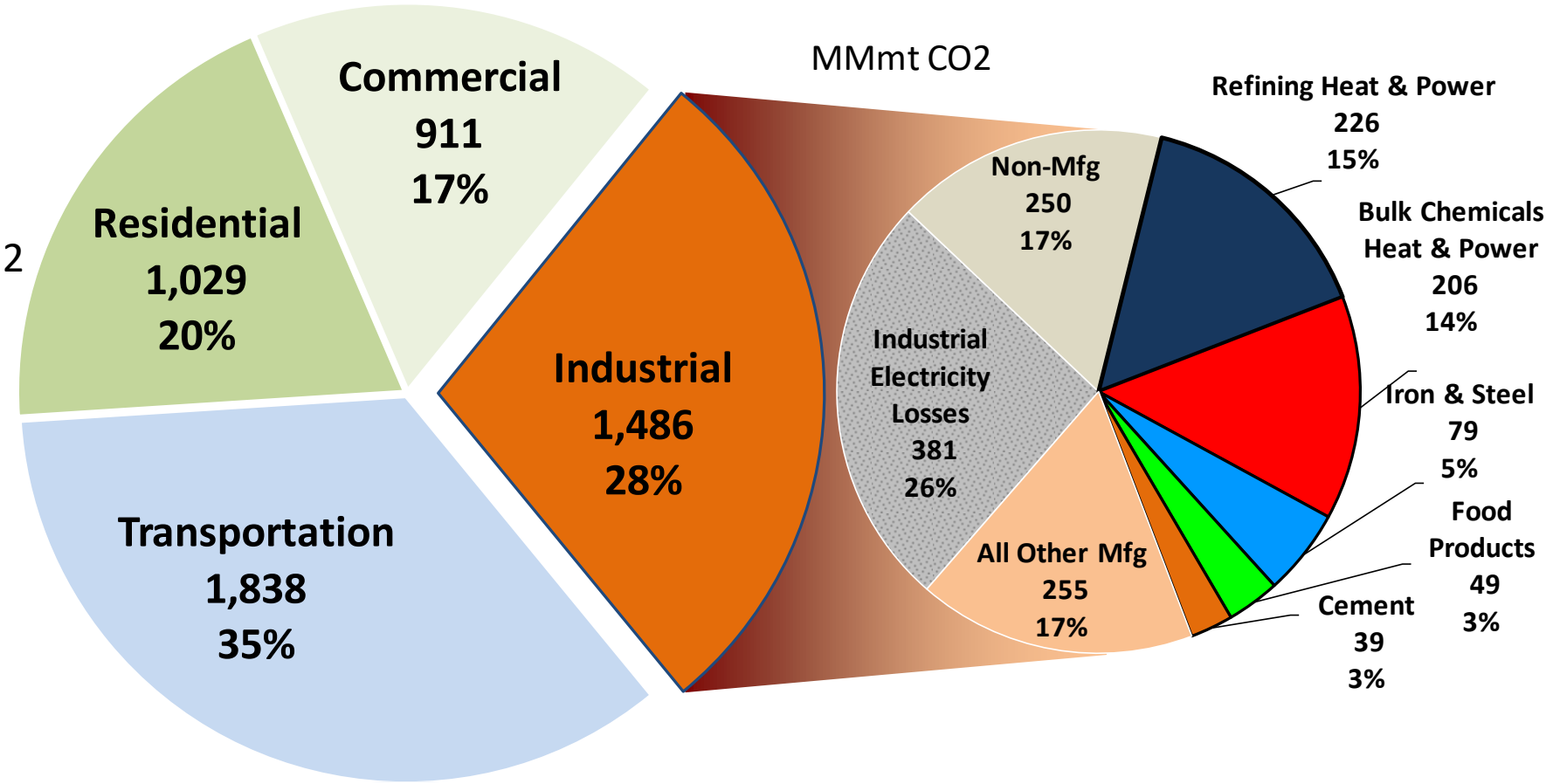
- Industrial energy use & GHG emissions
- Decarbonization strategies & pillars
- Roadmaps
- Pursuing opportunities

Industrial Energy Use & GHG Emissions

U.S. Energy-related CO_2 Emissions in 2015

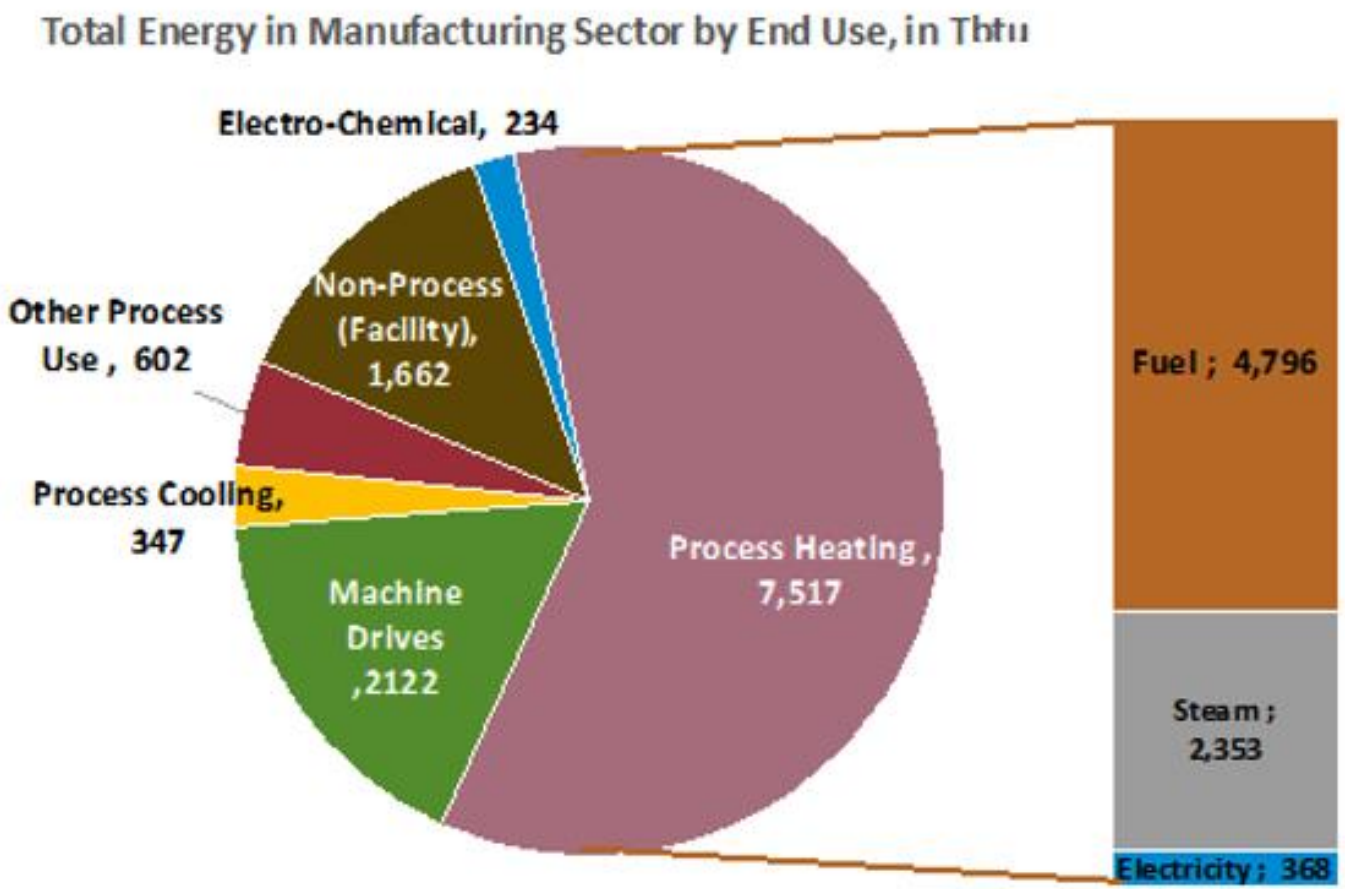
Five sectors - 70% of CO_2

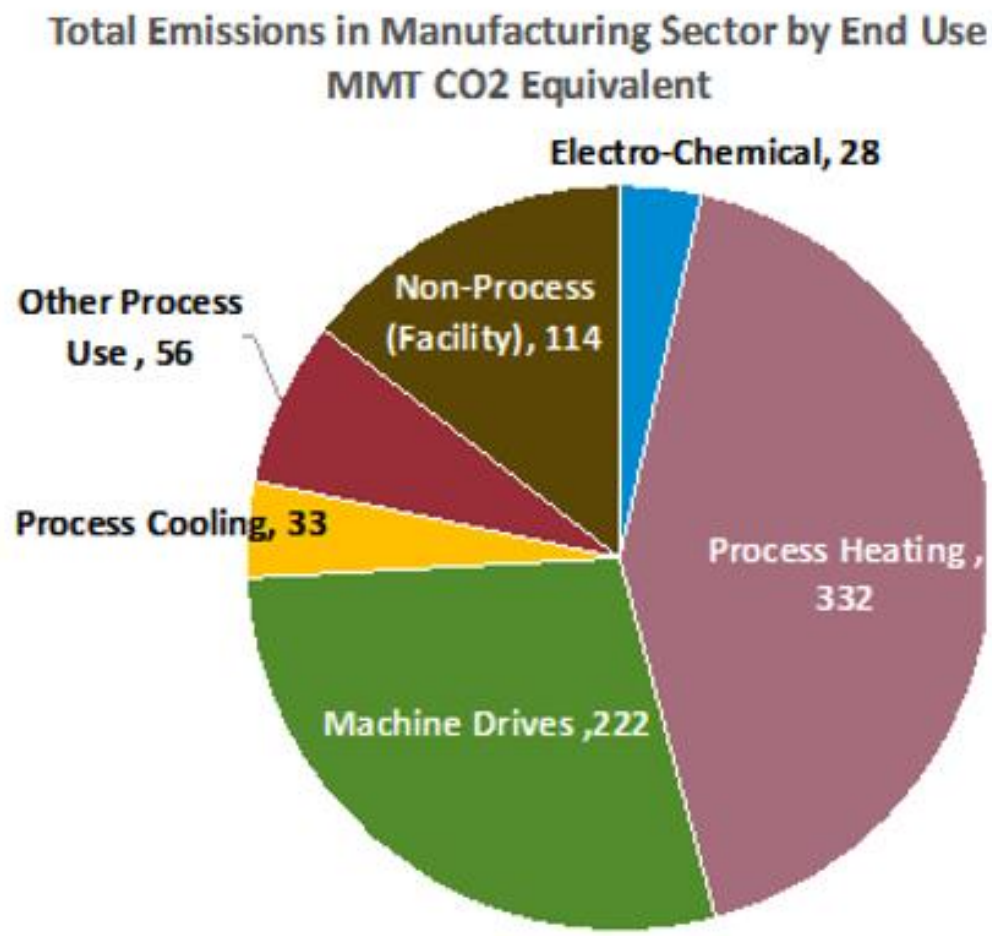
- Refining
- Chemicals
- Iron & Steel
- Food
- Cement



Data source: AEO 2020

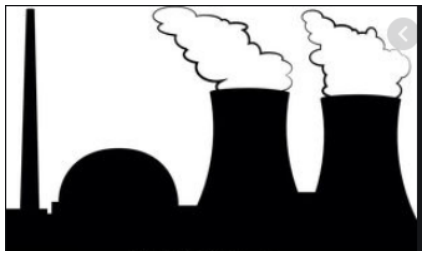
Industrial Energy Use & GHG Emissions

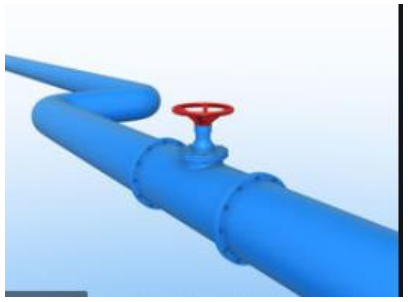




Data Source: MECS 2014

Decarbonization Strategies & Pillars





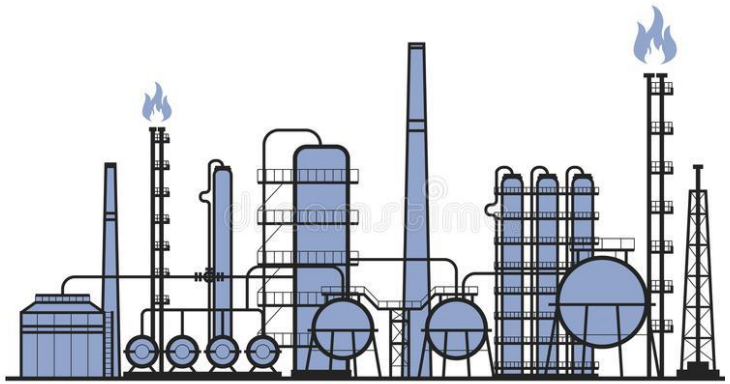


Image source: ssir.org

Decarbonize power, feedstocks, and materials inputs

Decarbonize processes, process heat, make every energy unit count

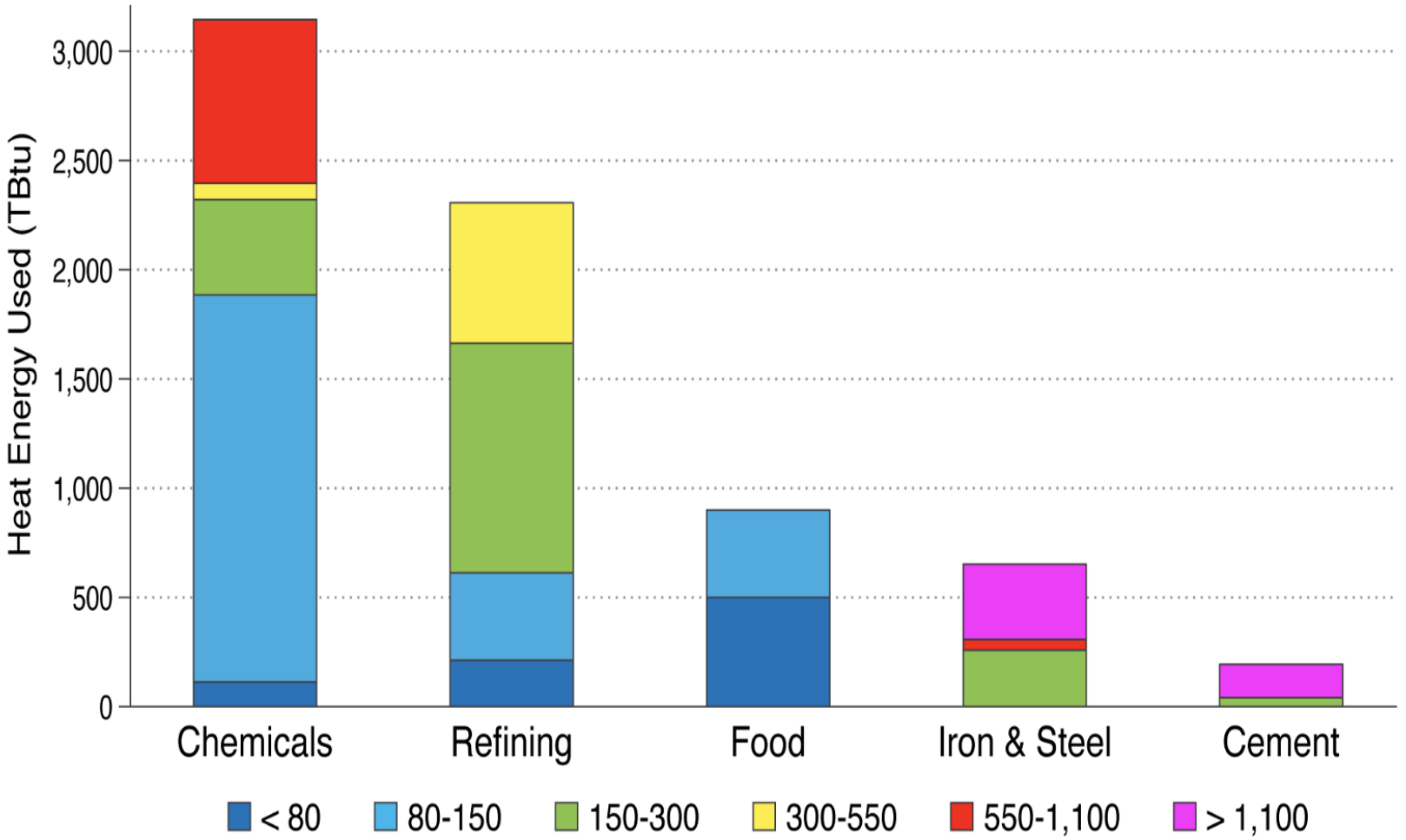
Decarbonize supply chains

Increase market pull for low-carbon products

Roadmaps: Process Heat

Process Heat

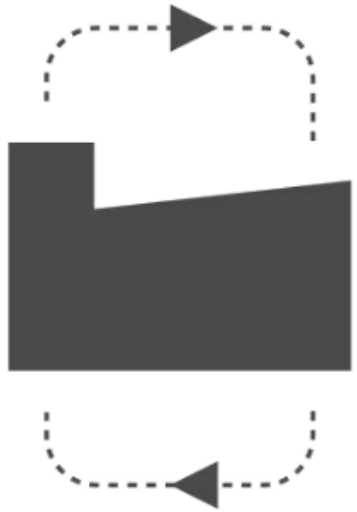
- 60% of GHGs are associated with heating
- another 3% with cooling
- Process heat is a cross-cutting opportunity



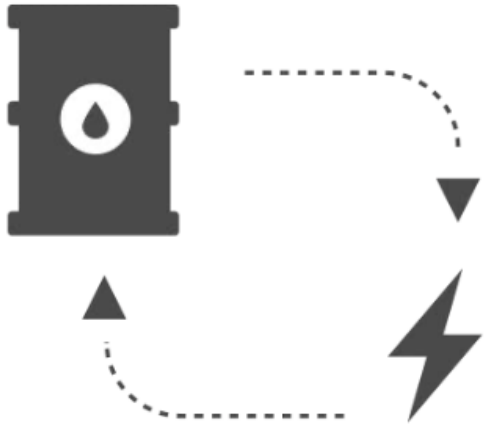
Temperature ranges in °C

Data Source: McMillan 2019

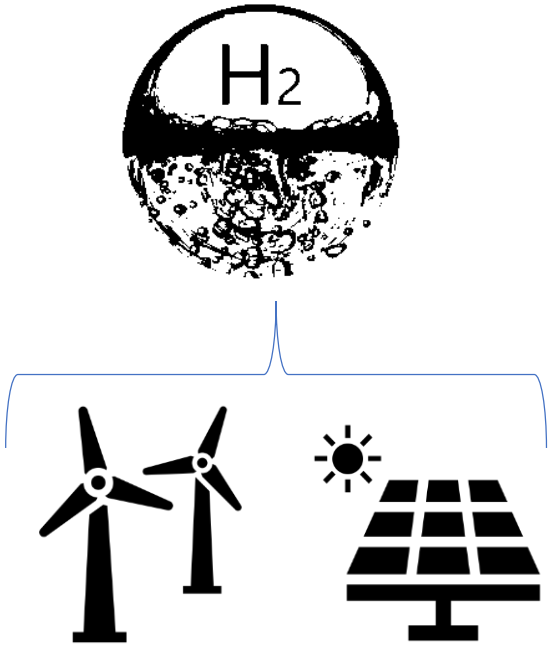
Decarbonization Strategies & Pillars



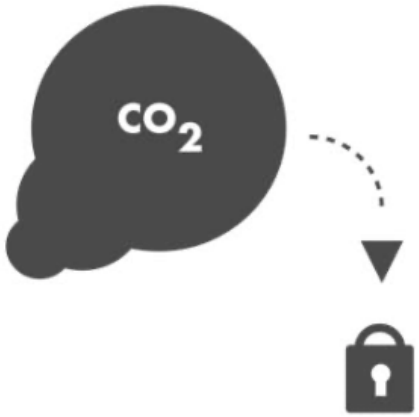
Energy Efficiency (EE)



Energy Substitution (ES)

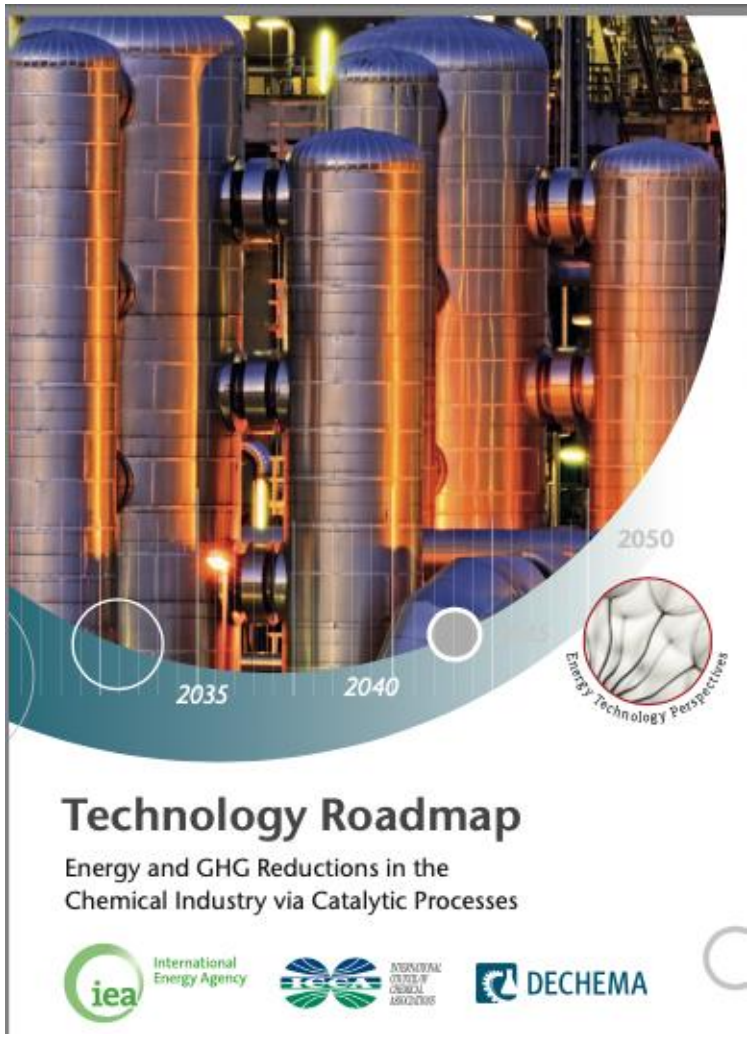


Low-Carbon Fuels & Feedstocks (LCFF)

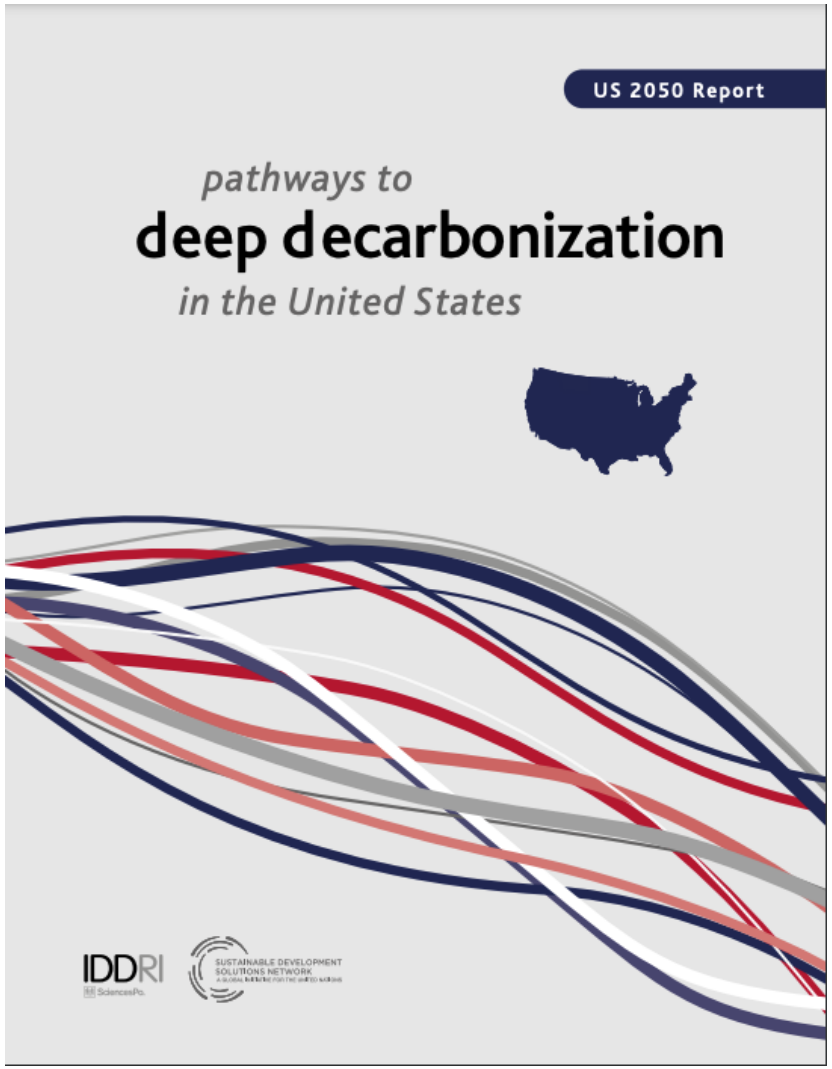


Mitigation Options, including, Carbon Capture Utilization & Storage (CCUS)

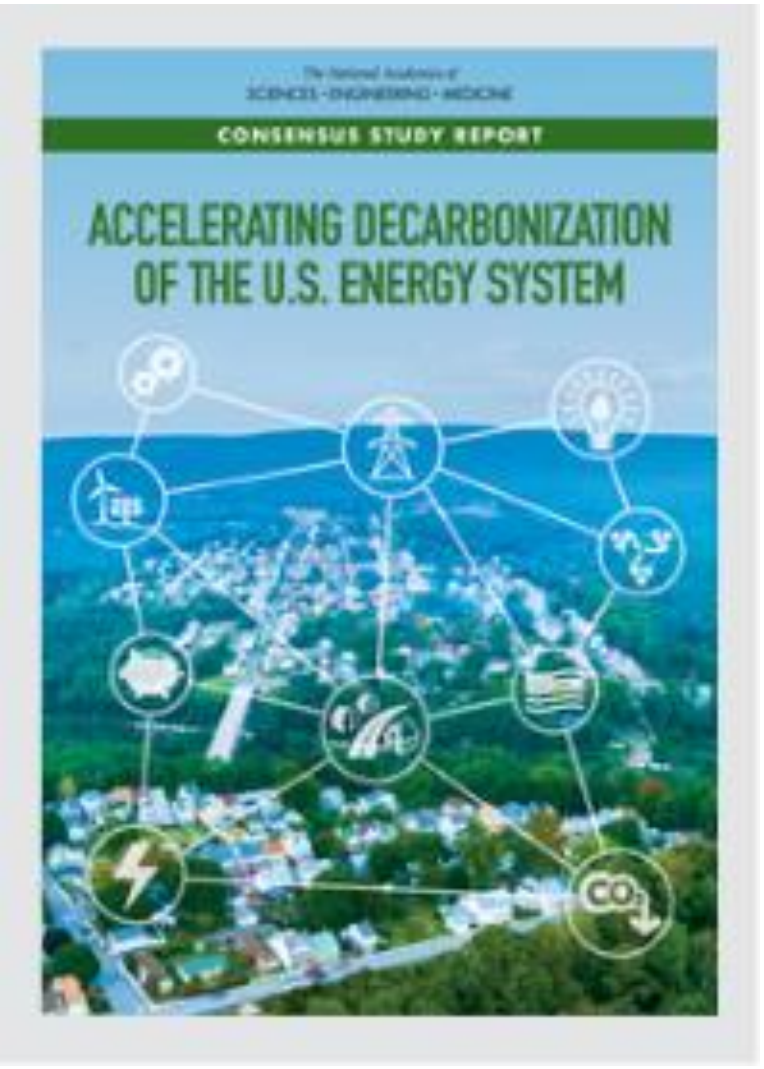
Roadmaps (a selection …)



ICCA, IEA, Dechema. 2013

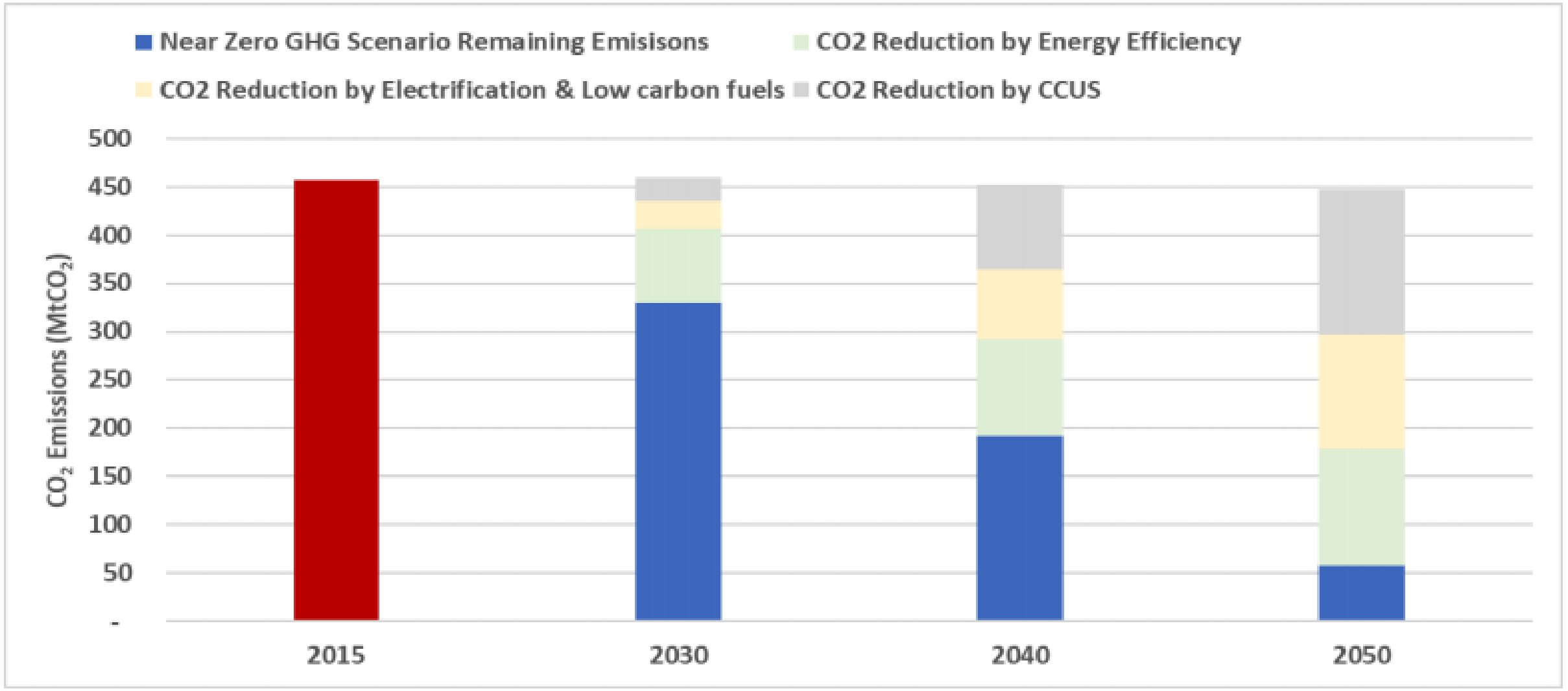


E3, LBNL, PNNL, 2014



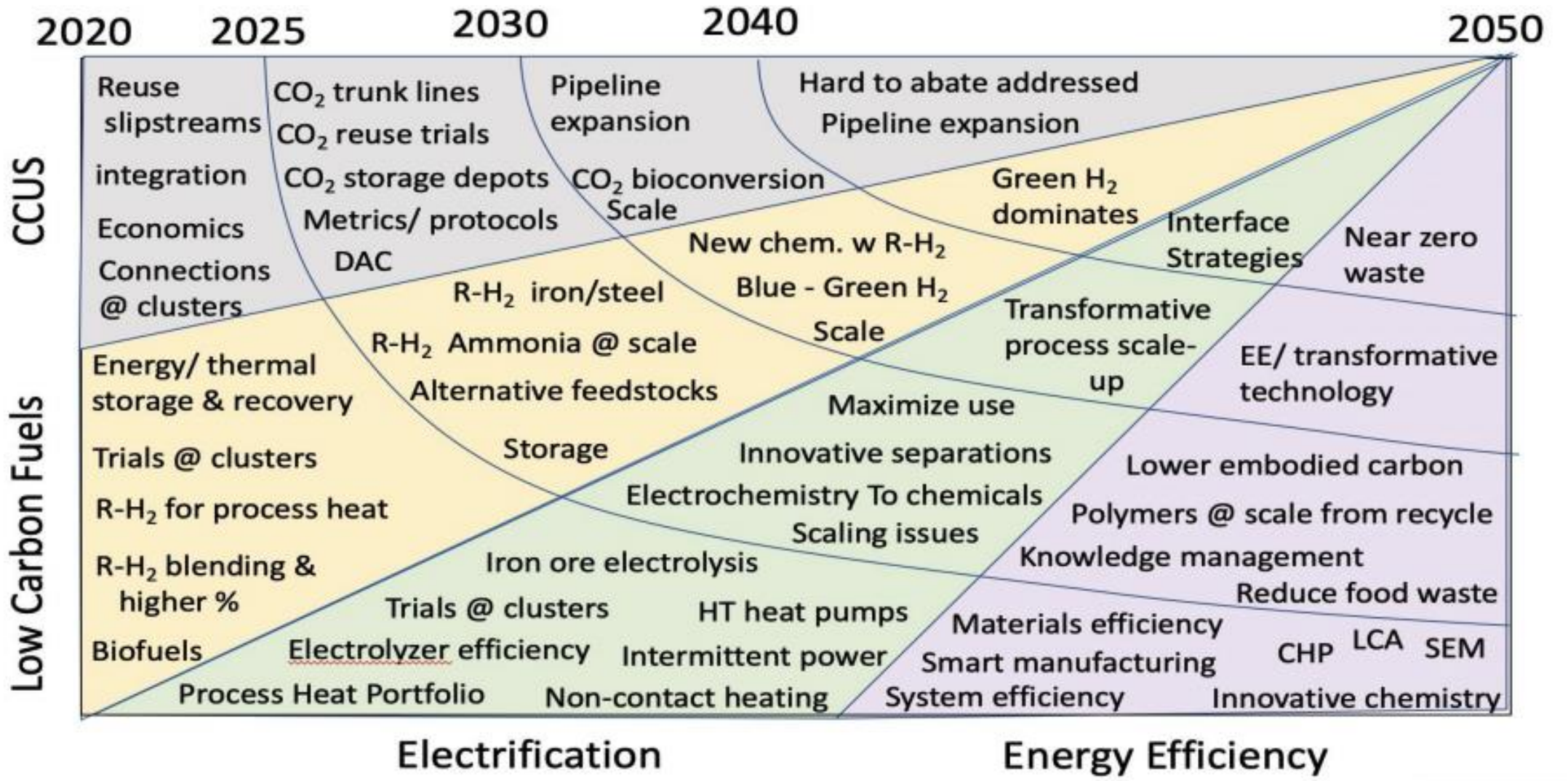
NAS, 2021

Roadmaps: GHG Reduction Potential Across Pillars



Source: Cresko, 2020

Roadmaps: Landscape of RD&D Decarbonization Opportunities



Source: Cresko, 2020

Pursuing Opportunities

Barriers & Opportunities

Industrial heterogeneity

Incumbent technology & practices

High technology costs

Low current energy costs

Scale-up

Key Innovation Areas

Smart manufacturing

Innovative Separations

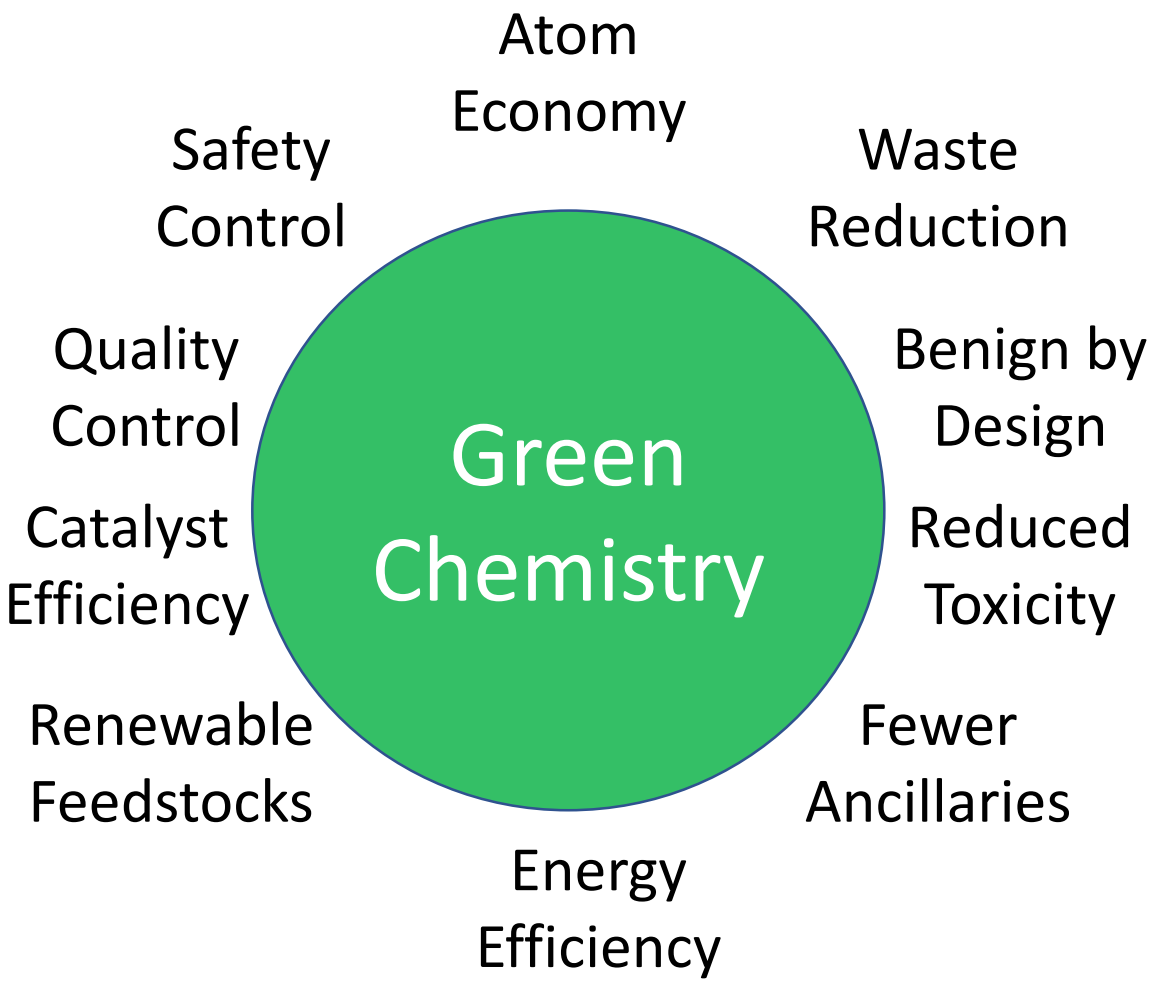
Electrolyzer efficiency

Thermal, electrical storage

Systems efficiency

Pursuing Opportunities: Innovative Process Technology

- The carbon discontinuity is an opportunity for process redesign. Step-reductions in;
  - carbon intensity
  - waste
  - Impacts (air, land, water…)
- Green chemistry & engineering
- Circular economy
- New routes to chemicals, design for recycling, electrochemistry…



Pursuing Opportunities: Call to Action

- Roadmaps describe the opportunity
- New white spaces for innovation
- The vision is less clear further out
- Time to pursue transformative change

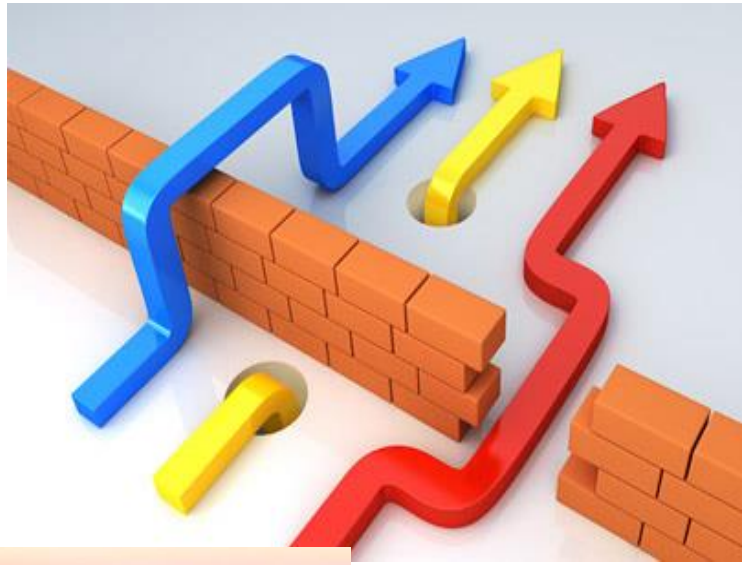


Image source: Change Factory

Image source: Drew Beamer, Upsplash

Select References

- Annual Energy Outlook (AEO), U.S. Energy Information Administration. 2020. https://www.eia.gov/outlooks/aeo/pdf/aeo2020.pdf
- Cresko, J., Industrial Decarbonization: Opportunity, Challenges and RD&D Needs, FE/NETL Carbon Utilization Program Review, https://netl.doe.gov/sites/default/files/netl-file/20VPRCU_Cresko.pdf
- Environmental Protection Agency (EPA), GHG Reporting Program, 2020, https://www.epa.gov/ghgreporting/ghg-reporting-program-data-sets
- US Department of Energy (DOE). 2018. Manufacturing Energy and Carbon Footprints (MECS). Retrieved from https://www.energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2014-mecs.
- International Council of Chemical Associations (ICCA), Technology Roadmap: Energy and GHG Reductions in the Chemical Industry via Catalytic Processes. IEA, ICCA, Dechema, 2013. https://www.americanchemistry.com/Catalysis-Roadmap/
- McMillan, C., Manufacturing Thermal Energy Use in 2014. 2019. National Renewable Energy Laboratory. dx.doi.org/10.7799/1570008. https://inldigitallibrary.inl.gov/sites/sti/sti/7365828.pdf
- National Academy of Sciences (NAS), Accelerating Decarbonization of the U.S. Energy System, 2021, https://nap.edu/resource/25932/interactive/#
- Rightor, E, Whitlock, A., Elliott, E, Beneficial Electrification, ACEEE, 2020, https://www.aceee.org/research-report/ie2002
- Williams, J.H., B. Haley, F. Kahrl, J. Moore, A.D. Jones, M.S. Torn, H. McJeon (2014). Pathways to deep decarbonization in the United States. https://biotech.law.lsu.edu/blog/US-Deep-Decarbonization-Report.pdf

Questions

Ed Rightor

ACEEE

erightor@aceee.org